# Regional Analyses of Restoration Planning

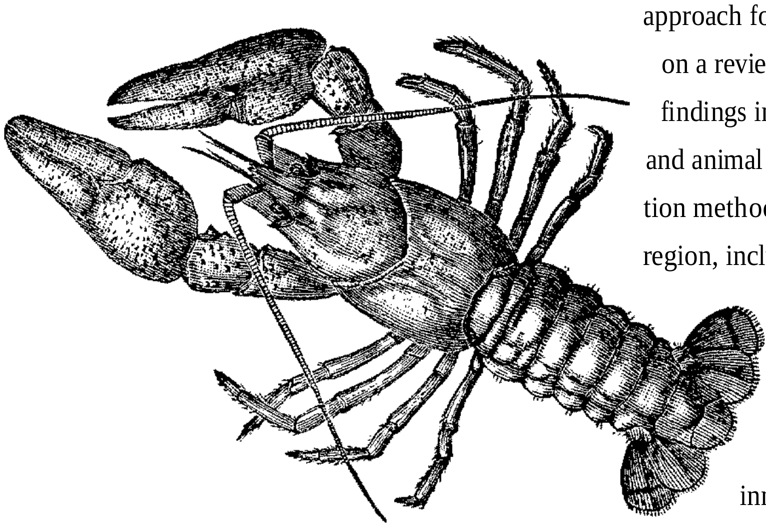
## PART 5 – NORTHEAST ATLANTIC

### ESTUARIES OF THE NORTHEAST ATLANTIC

The Northeast Atlantic region is defined here as the coastal and estuarine areas of the District of Columbia and the states of Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland and Virginia.

This region:

- Includes 103 estuarine and coastal drainage areas (NOAA, 1990).
- Covers more than 70,000 square miles in area (NOAA, 1990).



### SUMMARY

The Northeast Atlantic region is home to some of the most densely populated metropolitan areas, including New York City, Washington D.C., and Boston. Some threats to estuarine habitats and species of concern in all the Northeast Atlantic subregions include coastal development, urban runoff, sewage and septic releases, toxins, overharvesting of fisheries species, invasion by Phragmites australis sea level rise, and subsidence (see Table 3 for a complete list of key threats to estuarine habitats and species of concern in the northeast). An excellent monitoring protocol for tidal marshes has been developed through the Global Programme of Action for the Gulf of Maine and can serve as a model for other restoration programs. Examples of effective partnerships and community involvement include the Maryland Department of Natural Resources' Bay Grass Restoration Partnership. This partnership provides a coordinated approach for promoting citizen-based restoration of bay grass. Based on a review of restoration plans in the Northeast Atlantic region, findings indicate that dozens of endangered and threatened plant and animal species depend on Northeast estuaries. Several key restoration methodologies are being implemented in the Northeast Atlantic region, including a new method currently being developed for submerged aquatic vegetation (SAV) transplantation that is being tested by scientists at the University of New Hampshire. This method is referred to as Transplanting Eelgrass Remotely using Frame Systems (TERFS) and is innovative in that it does not require the use of divers.

Another successful method in this region is the restoration of shellfish beds through the distribution of clean shells or artificial substrate as a settlement substrate. In the Chesapeake Bay area, an experimental technique is being applied using marine limestone as an alternative substrate for restoring oyster reefs.

## Introduction to the Northeast Atlantic

### Description

For this discussion, the Northeast Atlantic is defined as the coastal region of the United States from the Maine-Canada border to the southernmost extent of Chesapeake Bay. This region includes 103 estuarine and coastal drainage areas that cover several thousand square miles in area (see Table 1) (NOAA, 1990). For this analysis, the Northeast Atlantic region is divided into three subregions: the Gulf of Maine (Maine-Canada border south to Cape Cod, Massachusetts); Southern New England/New York Bight (Buzzards Bay, Massachusetts, south to the Hudson-Raritan Estuary, New York/New Jersey); and Mid-Atlantic (Barnegat Bay, New Jersey, south to the Chesapeake Bay, Virginia) (see Figure 1). To ensure that this document complements existing programs and projects, these regions and subregions have been chosen on the basis of existing ecological boundaries used in other planning efforts (e.g., NOAA's Coastal Assessment and Data Synthesis/Coastal Assessment Framework; NOAA's Our Living Oceans Habitat Report; The Nature Conservancy's ecoregional planning process; U.S. Fish and Wildlife Service regions and programs; Gulf of Maine Council).

Six of the ten most populous watersheds are found in the Northeast (Hudson/Raritan, Chesapeake Bay, Long Island Sound, Delaware Bay, Great South Bay and Massachusetts Bay). The entire populations of Rhode Island, Connecticut, Delaware, and the District of Columbia fall within coastal counties, as does more than 90 percent of the populations of Maine, Massachusetts, New Jersey and Maryland and at least 67 percent of the population of New Hampshire, New York and Virginia (NOAA, 1999b). Humans place a high value on estuarine areas for living, working and enjoying recreational activities. Estuaries provide cooling waters for industry, and energy production and sites for aquaculture; accommodate the needs of large ships and tanker traffic; buffer coastal areas against storm and wave damage; provide wetlands and bottom habitat; supply space for coastal development; and filter pollutants from the rivers and streams entering coastal waters (USGS, 1998).

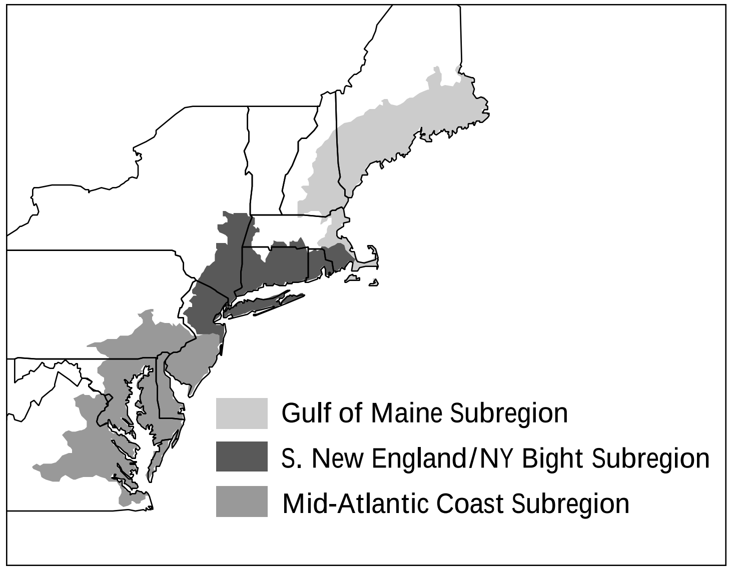



*Figure 1. Northeast Atlantic Region and Subregions*

### Key Habitats and Species

The primary estuarine habitat types found within the Northeast Atlantic region include tidal marshes, submerged aquatic vegetation (SAV), diadromous fish corridors, coastal embayments, shellfish beds, beaches and dunes, intertidal flats, salt ponds and salt pannes, and rocky shores and cobble beaches. The importance of each habitat and its need for restoration, based upon the frequency with which it was mentioned in the restoration plans reviewed, vary somewhat among subregions (see Table 2) although the values and function remain relatively uniform throughout the region.

**Table 1. Population and Areal Extent of Northeast Estuaries**

| Northeast Subregions | Estuarine Drainage Area Pop. (1990 Census) | Watershed Pop. (1990 Census) | Estuarine Drainage Area (sq. mi.) | Total Drainage Area (sq. mi.) |
|---|---|---|---|---|
| Gulf of Maine | 5,208,288 | 5,974,927 | 23,300 | 36,100 |
| S. New England/ New York Bight | 22,490,075 | 24,939,807 | 18,800 | 37,300 |
| Mid-Atlantic | 16,215,450 | 22,713,340 | 29,500 | 85,500 |
| TOTALS | 43,915,803 | 53,630,064 | 71,600 | 158,900 |

Source: NOAA, 1990

**Note:** *An Estuarine Drainage Area (EDA) is that component of an estuary's entire watershed that empties directly into the estuary and is affected by tides. EDAs may be composed of a portion of a single hydrologic unit, an entire hydrologic unit, more than one hydrologic unit, or several complete hydrologic units and portions or several adjacent hydrologic units. Every EDA has both a land and water component, with the land portion comprising a mainland component and, for certain EDAs, an island component. Total Drainage Area (TDA) is the EDA plus the fluvial drainage area.*

Marshes provide a broad range of functions and values for a wide variety of living resources. A number of important forage fish species utilize the marsh environment including killifish *(Fundulus majalis)*, Atlantic silversides *(Menidia menidia)* and mummichogs *(Fundulus heteroclitus)*, all of which are vital components to the overall estuarine and marine food web. These species use marsh grasses for protection from storms, as refuge from wave energy, as visual barriers from predators, and as a food source. For a broader range of species (flounder, mussels, calico crab, butterfish), the marsh habitat provides spawning and nursery grounds. Marshes provide aesthetic viewsheds and recreational opportunities for people, serve as stormwater containment, bind certain pollutants and prevent them from re-entering the water column, and contribute to groundwater recharge.

**Table 2. Estuarine Habitats in Need of Restoration in the Northeast Atlantic Region**

| Habitat | Gulf of Maine | S. New England/ NY Bight | Mid-Atlantic |
|---|---|---|---|
| Tidal salt marsh | ● | ● | ● |
| Submerged aquatic vegetation | ● | ● | ● |
| Diadromous fish corridors | ● | ● | ● |
| Coastal embayments | ● | ● | ● |
| Shellfish beds | ● | ▲ | ● |
| Beaches/dunes | ● | ● | ● |
| Intertidal flats | ● | ▲ | ▲ |
| Salt ponds/ salt pannes | ▲ | ▲ | ❍ |
| Rocky shore/ cobble beach | ▲ | ❍ | ❍ |

**KEY:** ● High need ▲ Moderate need ❍ Low or no need

Submerged aquatic vegetation (SAV) serves a number of critical functions within the estuarine system. As primary producers they photosynthesize, releasing oxygen into the water column while removing carbons. Blades of seagrass dampen tidal currents resulting in a low velocity zone within the bed itself. The rooted nature of the plants also stabilizes underlying substrates, which prevents scouring and erosion of the bottom. In addition to primary productivity and erosion control, much of the value placed on SAV comes from its function as a highly productive marine finfish and shellfish nursery and refuge habitat. Eelgrass and other SAV species are often associated with or located near shellfish beds. These beds also provide a food source or forage area for finfish, crab, and birds in the form of adult, seed and larval shellfish, and associated organisms.

Submerged aquatic vegetation (SAV) beds are used as attachment sites by the American oyster *(Crassostrea virginica)* during its juvenile state and by the bay scallop *(Argopecten irradians)* during its post-larval period. Juvenile finfish, including winter flounder *(Pseudopleuronectes americanus)*, black sea bass *(Centropristis striata)* and scup *(Stenotomus chrysops)*, utilize SAV beds as a refuge from storm surge and predators. They also depend on SAV as a direct food source and an indirect food source in the form of epiphytes and suspended particles. Adult finfish spawn in the protection of the beds where the eggs can be safely laid in the sediment or attached to the blades. Many forage fish, such as mummichog *(Fundulus heteroclitus)*, Atlantic silversides *(Menidia menidia)* and striped killifish *(Fundulus majalis)*, utilize the SAV beds as refuge from storm surge and predators.

Generally found in areas of soft or consolidated sand and silts, optimal shellfish beds within the northeast are typically zones of higher dissolved oxygen and improved water quality and clarity due to the strong filtration rate of shellfish. Oyster reefs filter impurities and pollutants from the water column. Reef habitats provide forage and protection areas for small finfish and crustaceans, which use the algae growing on the structure for food, and the diversity of the reef surface for hiding from predators.

Intertidal flats are habitat for a diverse array of invertebrates, including amphipods, polychaetes and shellfish. This habitat also provides forage area for fish and migrating shore birds. Intertidal flats also are productive shellfish bed and reef habitat, providing a valuable commercial and recreational resource. The shallow water associated with tidal flats, which is too deep for some shorebirds but too shallow for certain predatory fish, acts as a refuge area for juvenile and small fish.

A review of restoration plans indicated that dozens of plant and animal species that are endangered, threatened or of concern, such as the bald eagle, diamondback terrapin, Shortnose sturgeon, Atlantic salmon, eelgrass and American lobster, depend on the Northeast Atlantic region. Many species important to the economy of the Northeast, including commercial and recreational fisheries, depend on estuaries. Northeast estuaries are ecologically significant habitats providing food, shelter and nursery areas for a variety of living resources: plants, invertebrates, fish, reptiles and mammals. Shrimp, menhaden, oysters, flounders and blue crab utilize estuarine habitats for part or all of their life cycles, and Atlantic salmon and Atlantic herring require or prefer estuary areas at some time of the year (USGS, 1998).

The health of non-estuarine habitats, such as coastal grasslands, riparian areas, coastal forests and nontidal wetlands, often has an impact on the health of estuarine habitats. Protection and restoration efforts for these habitats may positively benefit species such as American eel, shad and blue-back herring, as well as promote the downstream drift of clean sediments and vital nutrients into the estuary. Shad and blue-back herring utilize freshwater habitats upstream of the tidal estuarine system as spawning and nursery grounds and return to coastal habitats. These species are commercially important and serve as prey for sport fish such as striped bass. Restoration of historic anadromous fish runs is a critical component of the restoration of estuarine ecosystems of the northeast.

The restoration of diadromous fish to rivers and streams is usually accomplished with either the complete removal of the dam or other obstruction to fish migration or the installation of fish passage structures (dam notches, fish ladders, elevators, baffles, appropriately sized culverts, step pools) where obstructions cannot be removed. In either case, the fish are once again able to access ancestral spawning grounds upriver. In rare cases, fish may have to be restocked into a water body where they have been eradicated by the presence of obstructions over a long period of time. Removal of obstructions or installation of fish passages is often accompanied by restoration of in-stream habitat such as natural stream meanders, placement of boulders, restoration of riffles and pools, and riparian plantings to restore streambank vegetation. These methods help ensure that the fish will encounter a hospitable environment on their way to and from their spawning areas.

*Status and Trends of the Northeast Atlantic Region*

A significant portion of the coastal habitats within the northeast have been altered, degraded or destroyed by anthropogenic activities. By the late 1930s, about 90 percent of the marshes of the northeast U.S. coast had been extensively ditched to control mosquitoes (Nixon, 1982). Filling and diking of marshland for dredging operations, road construction and commercial and residential development have led to the direct loss of wetland complexes. Table 3 summarizes some of the major past, present and future threats to estuaries in the Northeast Atlantic region. This table is not meant to be comprehensive but rather provides a few examples of key threats in this region.

Threats to tidal marshes are primarily related to tidal restrictions and other hydrologic alterations, filling and runoff from impervious surfaces. Tidal restriction, such as undersized culverts, causeways and tide gates, reduce the magnitude of tidal flushing and frequency, which in turn lowers substrate salinity, may impact elevation of the marsh, and reduces sediment transfer. Each of these factors may result in lost functions and values of a salt marsh as upland vegetation and opportunistic species (*Phragmites australis*, purple loosestrife) are allowed to colonize the marsh. Filling marshes for commercial development, as a component of road construction or as a dredge spoil disposal site creates a similar loss of ecological value and functions as do tidal restrictions, usually within a shorter time period. Hydrologic alterations in the form of ditching, dredging activity or changes in water flow may create increased water velocity through wetlands or expedite surface draining, thereby reducing substrate salinity and promoting opportunistic species invasion.

Impaired water clarity and increased colonization by epiphytes, caused by nutrient input or algal blooms, shades out submerged aquatic vegetation (SAV) and has been shown to destroy entire beds. In the 1930s, a "wasting disease" destroyed eelgrass populations along the east coast. Recolonization has been very slow, with small resurgences of the disease reported in many estuaries. Excessive and repeated boat wakes are believed to uproot aquatic vegetation, while a number of opportunistic species of bacteria, algae and even slime molds outcompete SAV populations by colonizing them as epiphytes. Changes in local hydrology and stronger currents can also damage the beds. Finally, the mechanical harvests of shellfish associated with these beds (such as scallops and clams) have also been shown to adversely impact SAV habitat.

Shellfish beds are threatened by a number of factors, including harmful algal events, diminished water quality, effluent wastes, siltation and other pollutants, decline of brood stock, overharvesting, shellfish parasites and diseases (MSX, Dermo and QPX), and increased predation by opportunistic species. Many historic oyster reefs in the Northeast Atlantic region have been lost to disease such as MSX and Dermo, sedimentation, excessive predation and harvesting, alterations in hydrology, and contamination by chemicals, effluents and oil. Other threats may include the reduction of brood stock or accidental destruction by boat traffic.

Historically, intertidal flats have been filled for development and land expansion. Since tidal flats often are located within

## Table 3. Key Threats to Estuarine Habitats and Species of Concern in the Northeast Atlantic Region

| General Threat | Specific Threat | Gulf of Maine | S. New England/ NY Bight | Mid-Atlantic |
|---|---|---|---|---|
| Direct habitat alteration | Coastal development | ● | ● | ● |
| | Dredging | ▲ | ● | ● |
| | Filling | ▲ | ▲ | ▲ |
| | Tidal restriction | ● | ● | ▲ |
| | Dams | ● | ● | ▲ |
| | Mosquito ditching | ● | ● | ▲ |
| Point and nonpoint source pollution | Urban runoff | ● | ● | ● |
| | Agricultural runoff | ▲ | ▲ | ● |
| | Pathogens | ● | ● | ● |
| | Aquaculture | ● | ❍ | ❍ |
| | Sewage and septic | ● | ● | ● |
| | Toxins | ● | ● | ● |
| Resource harvesting and extraction | Forestry | ▲ | ▲ | ▲ |
| | Mining | ▲ | ▲ | ▲ |
| | Fisheries | ● | ● | ● |
| Nuisance, exotic and invasive species | *Phragmites australis* | ● | ● | ● |
| | Purple loosestrife | ● | ● | ▲ |
| | Canada geese | ▲ | ● | ● |
| Natural disturbance | Ice scour | ❍ | ▲ | ❍ |
| | Sea level rise and subsidence | ● | ● | ● |
| | Predation and grazing | ▲ | ▲ | ▲ |
| | Storms | ▲ | ▲ | ▲ |

**KEY:** ● High concern ▲ Medium concern ❍ Low or no concern

*Phragmites australis *is native to the northeast (see sidebar below). However, it can outcompete other native vegetation and create a monocultural marsh habitat.*

**A note about the common reed *(Phragmites australis)***

We know from paleoecological research (data from peat cores) that *Phragmites* is a native plant in the northeast (and other regions of the United States). However, it is now apparently becoming more invasive (Orson et al., 1997; Weinstein et al., 2000) and is widely thought to be degrading essential marsh functions over much of its range. Large amounts of money and effort are being expended to eradicate, control and prevent *Phragmites*, using herbicides, mowing, burning, tidal flow restoration and other methods. Recent research indicates that the problems associated with *Phragmites* may be more perceived than documented. Some *Phragmites*marshes, once thought to be degraded, are much more productive and diverse than any salt marsh counterpart. More research is needed to determine why *Phragmites* is expanding so rapidly and to determine the extent to which it affects habitat quality for fish and wildlife, alters the marsh landscape and its function, reduces ecological diversity and contributes nutrients to the food web. This research will help determine if *Phragmites* should be managed as part of the landscape rather than eradicated. In the fall of 2001, a workshop and symposium was sponsored by USGS and Sea Grant, in New Jersey to provide more insight into the *Phragmites* issue. In any event, restoration of *Phragmites*-dominated marshes should be evaluated based on historic patterns, and research should demonstrate on a site-by-site basis that replacing a *Phragmites*-dominated marsh is truly worth the effort and money spent.

well-protected areas, many are dredged for use as boating facilities. Threats and impacts related to development and conversion for boating use include direct loss of habitat; loss of shallow water habitat; increased freshwater run-off; restricted or enhanced rate of water flow during tidal exchange; erosion and increased sediment transport out of the flats; and input of fuels, oil and other hydrocarbon pollutants. Other impacts related to human activities include disturbances related to overharvesting of shellfish and bait species of invertebrates, algal blooms from increased nutrient loading and alteration of hydroperiod.

Contamination by industrial and residential waste disposal and combined sewer overflow (CSO) events have degraded benthic and wetland surface habitats, reduced viable fish passage and resulted in the closure of shellfish area harvest because of threats to public health. Excess nutrient inputs due to failed septic systems, lawn fertilizers and CSOs along the coast can cause major algal blooms responsible for the degradation of shellfish and seagrass populations.

Bulkheading and other impervious shoreline structures have impeded the natural migration of tidal wetlands. The increase in impervious surfaces, such as roads and compacted earth, increases the potential for stormwater runoff that carries unburned fuels and additives, road salts and sand to estuaries and other coastal waters. Changes in sediment transport and hydrology due to inlet stabilization, culverts, dredging and boat wakes alter the dynamics of wetlands and shellfish beds. Impairments to these vital habitats can be directly linked to the decline of commercially valuable species, such as flounder, cod and scallops, and the overall health of the estuarine ecosystem. Tourism and recreational opportunities in coastal communities are dependent on the health and aesthetic qualities of estuarine habitats. Protection and restoration of these coastal environments also is crucial to the preservation of America's cultural, historic and economic resources.

## Regional Planning Efforts

Since the early 1970s, habitat restoration has been used increasingly in the Northeast Atlantic region as a means to reverse the trends of habitat loss and degradation. Today, all the northeast states have active and/or completed restoration projects within their boundaries. These restoration efforts occur under the auspices of federal, state and local authorities as well as through the efforts of nongovernmental entities such as business and industry groups, academic institutions, non-profit organizations and community groups. In addition, all states in the Northeast Atlantic region have made great strides in the past years to reduce contaminant loadings through permitting discharges.

As part of a Natural Resource Damage Assessment project, more than 250,000 Spartina alterniflora plants propagated from indigenous seeds were used to revegetate marshes in the Arthur Kill that were destroyed by the 1990 Exxon Bayway oil spill (NY-NJ Harbor Restoration Committee, 1995). In Rhode Island, a diverse array of partners (U.S. Army Corps of Engineers, Rhode Island Department of Environmental Management, U.S. Fish and Wildlife Service, Rhode Island Department of Transportation, University of Rhode Island, Save the Bay, and Ducks Unlimited), restored more than 128 acres of salt marsh and 14 acres of tidal creeks at the Galilee Sanctuary, formerly diked off from natural tidal flow and invaded by Phragmites, by removing fill and improving tidal exchange with innovative self-regulating tide gates (Hubbard, personal communication).

Since 1969, at least 1,600 acres of Connecticut's tidal wetlands at more than 50 sites have been restored to more productive use as habitat for fish, birds and plants. Fish passage structures on Rhode Island's rivers have opened more than 57 river miles of habitat to diadromous fish (Lipsky, personal communication; Narragansett Bay NEP, www.nbep.org).

Although there are geographic and ecologic differences among Northeast estuaries, common themes have emerged for important habitats, planning efforts, and information needs essential for the effective restoration of estuary structure and function. A number of agencies and organizations have undertaken restoration planning for coastal and estuarine habitats. Examples of some region-wide plans for the Northeast Atlantic are listed below. Additional plans and detailed information are available through the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

*Ducks Unlimited Conservation Plan*

This plan is the result of a continuing assessment of Ducks Unlimited's path to ensure it is still in tune with the needs of waterfowl and wetlands conservation. The plan outlines several important habitat areas, their importance to waterfowl, environmental risks, current conservation programs, goals, assumptions and strategies.

*Essential Fish Habitat Amendments to the Sustainable Fisheries Act*

The purpose of the amendments is to identify and describe essential fish habitat (EFH) for all species of marine, estuarine and anadromous finfish and mollusks managed by the New England Fishery Management Council to better protect, conserve and enhance this habitat. This amendment also identifies the major threats to EFH from fishing and non-fishing related activities and identifies conservation and enhancement measures.

*Partners in Flight: Conservation of Land Birds of the United States*

Partners In Flight (PIF) is a consortium of public and private organizations and individuals working to conserve land birds throughout the Western Hemisphere. PIF's guiding principles are to restore populations of the most imperiled species and to prevent other birds from becoming endangered - "to keep common birds common." The PIF partnership has developed a comprehensive set of regional Bird Conservation Plans (BCP) for land birds in the continental United States.

## Plan Elements

Many similarities were identified among plan elements for both regional and subregional plans in the Northeast. The discussion below is based on information from all the plans reviewed for the Northeast region, and is applicable to each subregion.

*Goals*

- A review of restoration plans with a national or regional focus identified similar goals among restoration efforts.
- Forming partnerships and cooperative efforts.
- Developing a strong scientific basis for restoration efforts or identifying this need.
- Setting priorities within a particular geographic zone or range, which varies for different species, habitats, demographics and threats.
- Defining the appropriate geographic scale for given restoration goals.
- Planning with an ecological approach, based on a clear understanding of the cause and effect within the key habitats of a given ecosystem.

*Methods*

Several restoration plans with a national or regional focus provide some information on methods that have been used or recommended for achieving the region's restoration goals. These methods are briefly outlined below, categorized by key habitats:

1. **Tidal marshes.** Restoration or creation most often involves reestablishing appropriate hydrology and hydroperiod by replacing undersized culverts, repairing malfunctioning tide gates, breaching dikes, removing invasive plants and reestablishing marsh vegetation, reconfiguring stream channels, and regrading the substrate to enhance sediment properties that support growth of marsh species. In areas where the marsh has been grid-ditched in the past for mosquito control, open marsh water management techniques are used to restore marsh function and control pests. In areas where nuisance and/or invasive species (e.g., *Phragmites,* purple loosestrife, water chestnut) are dominant, mowing, burning, herbicide, manipulation of water level and removal by hand may be necessary.

   A common restoration technique is the removal of *Phragmites* and its rhizome structures coupled with physical modification of the site and the planting of native salt marsh vegetation (most often *Spartina alterniflora, Spartina patens,* or other species of concern). Other actions can help restore tidal marshes while maintaining the function of traditional structures. Surface vegetation and substrate can be restored by replacing shoreline hardening such as a bulkheads and riprap with bioengineering (soft solutions) devices such as planted geo-textile tubes. Wave energy deflected off bulkheads and riprap walls can lead to erosion of the marsh surface. Bioengineering uses native vegetation and grading to stabilize coastal banks, absorbing wave energy and protecting the marsh from reflected energy and possible erosion. Standard storm drains can be replaced with systems designed to trap road sand, providing a mechanism to control flooding and to limit indirect filling of marsh surface and channels. Replacing flapper-style tide gates with self-regulating tide gates can maximize tidal exchange and provide flood control during spring tides and storm events.

2. **Submerged aquatic vegetation (SAV).** Restoration techniques for SAV are relatively new, and large-scale efforts have been primarily unsuccessful. Most SAV restoration was attempted by harvesting plants from donor beds and transplanting in locations known to historically support SAV. In some cases, the removal of sections of healthy beds adversely affects the remaining plants, and it is not uncommon for removal to severely impact the donor site. Donor plugs are planted using the staple method, horizontal rhizome method in areas conducive to growth (e.g., areas of relatively low wave velocity, areas of historic eelgrass growth). Transplanted plugs may not be capable of gaining enough root stability to survive storms or currents and may release from the substrate and be lost.

   Recently, new methodology and experimentation has begun to advance the science of SAV restoration through the use of seed and plugs collected from the shore following storms. Methods such as TERFS (Transplanting Eelgrass Remotely using Frame Systems), which creates an anchoring device to provide the plants with the necessary stability to allow development of root mass, and greenhouse germination of collected seed is being coupled with site selection criteria to add increased ecological benefits and success of SAV restoration projects. More importantly, efforts are increasing to protect seagrass habitats through proactive management (e.g., avoiding impacts or losses and reducing nutrient inputs).

3. **Shellfish beds.** Restoration efforts most often involve quahogs (*Mercenaria mercenaria*), oysters (*Crassostrea virginica*) and soft-shell clams (*Mya arenaria)*. Restoration or enhancement methods are distinct for each of these organisms. Oyster restoration involves the distribution of clean shell material as settlement substrate for juveniles and "seeding" of the shell material with sub-adult-stage oysters. Quahogs and clam beds are restored by spreading ("seeding") juvenile stage individuals over an open flat. This method can be enhanced by mixing juveniles with various size adults to create a range of year classes and by placing a protective cover over the seeded substrate to exclude predators. Once an area has been successfully restored, it is important to set aside refuge areas, closed to harvesting, as sources for brood stock or seeds. Properly managing the refuge and harvested areas can provide a self-sustaining shellfish population.

4. **Shellfish reefs.** Oyster reef restoration has advanced within the past decade throughout the region. The most common process is placing oyster or clam shell on the bottom to create a submerged, three-dimensional reef structure, mimicking the design of natural reefs. These new reefs are sometimes planted with juvenile oysters. Shellfish reefs also have been established or enhanced through the use of natural or artificial reef materials (e.g., shell, rock or stone, concrete modules, decommissioned ships). If shellfish have been totally eradicated from an area, the seeding or stocking of larval, juvenile and adult shellfish may be needed to jump-start the recruitment process.

5. **Intertidal flats.** A few intertidal flat restoration projects have been attempted in the Gulf of Maine, primarily connected with mitigation efforts at port facilities (e.g., Portsmouth, N.H., and Revere, Mass.). The restoration usually involves the removal of contaminated sediments and replacement with clean dredged material; removal of fill material and regrading substrate to re-establish the historic high tide line; the use of best management practices that include diversion of stormwater run-off and sediment control and reduction in the frequency of combined sewer overflow events to minimize nutrient input. Other restoration techniques include restoring historic tidal regime by removing or opening causeways, tide gates and culverts, seeding shellfish and establishing no-harvest areas.

### *Elements of Success*

Of the documents reviewed, most efforts identified the following elements of successful restoration.

- Restoration plans that are part of an overall estuary or watershed-wide plan.
- A priority-setting and ranking scheme to select potential restoration sites.
- A number of criteria for success or performance standards to gauge the progress of restoration projects after a project is completed.
- A series of appropriate local reference sites to provide a comparison between the restoration site and the desired outcome of the project.
- A well-designed pre- and post-project ecological monitoring program which ensures an evolution of knowledge from every restoration project to build on successes and adaptively manage as necessary.
- Sustainable funding to carry the project through completion and post-construction monitoring.
- A comprehensive education and outreach strategy to secure the support and involvement of stakeholders (e.g., general public, elected officials, grassroots groups) in the process.
- Public involvement in the project to generate support for the effort and provide volunteer assistance.
- Partnerships with government agencies, scientists, nonprofit organizations, private citizens, and the formation of multidisciplinary teams (e.g., scientists, planners, economists, community representatives) to create a consensus-based approach to project planning.
- The use of geographic information systems (GIS) for the identification of restoration sites, baseline mapping and the habitat inventory process.
- A standard database and tracking system to help gauge progress and identification of restoration projects toward regional restoration goals.

### *Information Needs*

From the plans reviewed for the Northeast Atlantic region, research and information are still needed.

- Creating a comprehensive region-wide inventory and mapping existing habitats, both functioning and degraded, to support restoration efforts.
- Gaining a better understanding of ecosystem structure, function and the effects of habitat alterations.
- Identifying indicators of impacts on and recovery of habitats and living marine resources.
- Developing criteria for selection and placement of restoration sites.
- Designating scientifically defensible criteria for restoration success and developing the best assessment methodology to

measure return of ecosystem functionality after restoration.

- Developing and testing of quantitative models, at several spatial scales, to predict recovery rates and success of restoration for all habitats, especially salt marsh and submerged aquatic vegetation (SAV).
- Providing technical and planning assistance for habitat restoration at the local and grassroots levels.
- Building partnerships with federal, state, provincial, municipal and nongovernmental organizations (e.g., land trusts, watershed associations), and landowners, to protect and restore estuary habitats.
- Predicting the impacts of climate change and rising sea level on restoration projects.
- Creating mechanisms for information exchange among scientists and restoration practitioners.

In the Northeast Atlantic region, materials and techniques are needed.

- Development and testing of new synthetic materials (nontoxic and cost-effective) for physical habitat manipulation.
- Beneficial use of dredged material for habitat restoration.
- Necessary and effective dimensions for riparian buffer zones.
- Research on the effectiveness of bioremediation at reducing contaminant levels.
- Development and implementation of cost-effective methods to control eutrophication, erosion and runoff (e.g., Total Maximum Daily Loads).

### Northeast Atlantic Subregions

Among the subregions of the Northeast Atlantic region, the functions and values, threats and concerns and research needs for estuarine habitats are similar. For example, a healthy tidal marsh in Massachusetts typically provides the same basic function and value as one in New Jersey or Maryland. It has similar threats from changing hydrology, tidal restriction and freshwater intrusion. However, subtle distinctions among the subregions , specifically with regard to threats, were identified that require further review and analysis. A subregional breakdown follows.

## Gulf of Maine Subregion

### Description

The Gulf of Maine is a semi-enclosed gulf bounded landward by the northeastern states of Maine, New Hampshire and Massachusetts, and the Canadian provinces of Nova Scotia and New Brunswick, and seaward by the north Atlantic Ocean. The Gulf of Maine is strongly influenced by both tides and freshwater inflow, primarily from the Androscoggin, Penobscot, Merrimack, and Kennebec rivers in Maine and the St. Croix and St. John Rivers in Canada. The Gulf of Maine includes more than 23,000 square miles of estuarine and coastal drainage area. Estuaries in this region were formed by glaciers that removed soil cover and left behind rocky shorelines and steep-sided river channels. These estuaries are smaller on average and generally deeper than those found in other regions (NOAA, 1990). The region is influenced by areas of dense human population (Boston, Mass., Portsmouth, N.H., Portland, Maine) as well as large rural, forested and agricultural areas (such as in northeast Maine). More than five million people live within the Gulf of Maine's estuarine drainage areas, and almost six million people live within watersheds that drain into the Gulf of Maine (NOAA, 1990).

Partnerships in this subregion are often multi-state and international, because the Gulf of Maine borders Massachusetts, New Hampshire and Maine and the Canadian provinces of New Brunswick and Nova Scotia.

### Habitat Issues

*Status and Trends*

Maine was third among all U.S. states, behind Alaska and Louisiana, in total value of commercial fishery products landed in 1999 ($265.2 million) (NMFS, 2000). Commercial fisheries in the Gulf of Maine have directly involved some 20,000 persons in harvesting more than 500,000 metric tons of fish and shellfish valued at $650 million each year (Apollonio and Mann, 1995). Lobsters, clams, mussels and marine worms have long been commercially important in various parts of the Gulf of Maine. It is estimated that in Maine alone, the annual value of the fishery for these three species is $13 to $15 million (Harvey et al., 1995). The port of Boston generates more than $2 billion in economic activity each year, and tourism in the area brings in about the same amount of income annually (Platt, 1998).

Many of the coastal habitats within the Gulf of Maine subregion have been altered, degraded, or destroyed. Of the original 11,771 acres of spawning and nursery habitat available to Atlantic salmon, only 52 percent (6,115 acres) remains in Maine's rivers today (USFWS, 1991). Of the approximately 6,200 acres of salt marsh remaining in New Hampshire, about 1,000 acres are seriously degraded by tidal restrictions or other problems (USDA, 1994). In Maine, many of the 255,608 acres of shellfish beds are periodically closed to harvesting, and other coastal areas are often closed to swimming because of bacterial contamination (Maine State Planning Office, 1997). Only about 15 percent of the original salt marshes remain in the Bay of Fundy region, and less than half remains along much of the rest of the Gulf of Maine coast (Burdick et al., 1994). Massachusetts has lost more than 50 percent of its original salt marsh acreage, and only 36,000 acres remain today in the Massachusetts Bay region (www.state.ma.us/massbays/habitat.pdf) .

However, since the early 1970s, habitat restoration has been increasingly used in the Gulf of Maine subregion to reverse the trends of habitat loss and degradation. More than 700 acres of salt marsh habitat have been enhanced or restored in New Hampshire since 1990 (New Hampshire Estuaries Program, www.epa.gov/owow/estuaries/nhe.htm). Since the early 1990s, more than 2,000 acres of degraded salt marsh habitat have been restored in the Gulf of Maine (Cornelison, 1998).

*Threats*

Hundreds of dams obstruct the migrations of diadromous fish (e.g., salmon, herring) to and from their spawning grounds, and diking and water control structures have converted more than half of the marshes in the Bay of Fundy to agricultural lands. In Massachusetts, New Hampshire and Maine, a majority of salt marshes have been ditched and drained for mosquito control, and roads and coastal development have severed links between land and sea. Dredging for public and private water access and dockage is resulting in a loss of shallow water habitat. Populations of waterfowl, seabirds and diadromous fish have declined significantly with increased pressures and impacts on coastal habitats. Less obvious impacts, such as poor water quality, have contaminated shellfish beds and decimated meadows of seagrass, which many species of fish and invertebrates depend on for survival (Cornelison, 1998.)

## Restoration Plans

Some examples of restoration plans in the Gulf of Maine subregion are listed below. Additional plans and detailed information is available through the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

*Casco Bay Comprehensive Conservation and Management Plan*

The Casco Bay Plan was developed through a collaborative process involving hundreds of individuals and dozens of organizations and government agencies. The plan's goal is to minimize adverse environmental impacts to ecological communities from the use and development of land and marine resources. Five priority issues of importance to the health of the bay are identified: stormwater, clam flats and swimming areas, habitat protection, toxic pollution, and stewardship. In addition, the plan also identifies actions to protect the bay (including public education, technical assistance, regulation and enforcement, and planning and assessment) as well as a detailed monitoring plan to measure progress in implementation of the plan.

*Great Bay National Estuarine Research Reserve*

The Great Bay National Estuarine Research Reserve was established in New Hampshire in 1989 and currently encompasses 5,280 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1989 and is currently being revised. Important habitats that may be useful for investigation and as reference sites include upland fields and mixed woods, salt marshes, mud flats, rocky intertidal areas, shellfish reefs and eelgrass beds. Restoration priorities include oyster reef and soft shell clam restoration and anadromous fish habitat restoration. Current restoration projects include eelgrass and salt marsh restoration, Phragmites control, and preparation of a restoration plan for coastal New Hampshire.

*Gulf of Maine Council Action Plan 2001-2006*

This plan is a sequel to the first ten-year Gulf of Maine Action Plan adopted in 1991 which defined priorities, objectives and timetables for cooperative work. This plan focuses on the next five years and identifies the Council's new focus on coastal and marine habitats.

*Management Plan for the Waquoit Bay National Estuarine Research Reserve*

The Waquoit Bay National Estuarine Research Reserve was established in Massachusetts in 1988 and currently encompasses 2,600 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 2001. Important habitats that may be useful for investigation and as reference sites include pine and oak forest, salt ponds, coastal sand plains, salt marsh, and barrier beaches and dunes. Restoration priorities include riverine habitat for sea run fish, eelgrass meadows and water column, coastal sand plain habitat, salt pond wetlands and coastal dunes. Current habitat restoration projects include nitrogen loading reduction, endangered plant restoration in a meadow area, controlled burns to maintain a coastal sand plain area, salt pond wetlands restoration, river restoration of sea trout and herring runs and coastal bird restoration by controlling human impacts in habitat areas.

*Management Plan for the Wells National Estuarine Research Reserve*

The Wells National Estuarine Research Reserve was established in Maine in 1984 and currently encompasses 1,600 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1996. Important habitats that may be useful for investigation and as reference sites include upland fields and forests, tidal rivers, salt marsh, forested wetlands, dune forest and beaches. Restoration priorities include regional restoration of tidal flow in salt marshes, control and elimination of invasive upland plants and restoration of fish passage for migratory fish in coastal watersheds. Current restoration projects include hydrological restoration of impounded salt marshes and shorebird restoration through monitoring and protection activities for least terns and piping plovers.

*Massachusetts Bays Comprehensive Conservation and Management Plan*

The Massachusetts Bays CCMP will serve as the blueprint for coordinated action among all levels of government to restore and protect water quality and the diverse natural resources of the Massachusetts Bays estuary. The plan provides specific information on the Bay's five coastal subregions as well as information on a number of major construction projects of regional scope and impact in the Bays region. The centerpiece of the plan is the outline of 15 major action plans for preserving and protecting the Bays' resources. Implementation of these action plans is presented as a series of targeted steps to be taken by federal, state and local agencies.

## Southern New England/New York Bight Subregion

### Description

The Southern New England/New York Bight subregion is characterized by a diverse system of sounds, bays, lagoons, harbors, coastal streams, tidal rivers, and associated habitat. Because the estuaries (Long Island Sound, Connecticut/New York, Hudson-Raritan, and New York/New Jersey Harbor) span multiple jurisdictions, partnerships are often multi-state. This area has been historically renowned for its rich fisheries, abundance of waterfowl, diverse wildlife, productive marshes, scenic beaches, and outstanding recreational opportunities. As one of the most populous and heavily industrial coastal areas in the world, it has also been an area of unprecedented human population growth—more than 22 million people live in this subregion's estuarine drainage area—and massive urban coastline development that in recent decades has resulted in dramatic declines in its living resources and the large-scale loss and degradation of essential estuarine and coastal habitats (NOAA, 1990; USFWS, 1991, 1997).

The estuaries of the Southern New England/New York Bight subregion are economically valuable. The fishing port of New Bedford, Mass., is second only to Dutch Harbor, Alaska, in value of commercial fishery products landed in 1999 (National Marine Fisheries Service, 2000). More than 90 percent of the Atlantic mackerel, an estuarine-dependent fish, caught in the United States in 1999 were landed in New Jersey (20 million pounds) and Rhode Island (4.3 million pounds) ports (National Marine Fisheries Service, 2000).

### Habitat Issues

*Status and Trends*

More than 35 percent of Long Island Sound's tidal wetlands have been lost over the past century (Long Island Sound Study, 1994). Dams are present on all of Rhode Island's major rivers, preventing or seriously limiting the spawning migration of diadromous fish. At least 33 percent of Narragansett Bay's shellfish beds (36,000 acres) are closed to harvest because of pathogen contamination. Rhode Island has lost 50 percent of its coastal wetlands since European colonization. Of those that remain, 70 percent suffer from restricted tidal flow, 60 percent are affected by dumping and filling activities and 60 percent are affected by invasive species (Lipsky, personal communication; Narragansett Bay NEP, www.nbep.org). Almost 75 percent of all tidal (fresh and salt) marshes in the Hudson-Raritan Estuary have been lost to development (Willner, personal communication).

*Threats*

The extinction and extirpation of several species of plants and animals in this area, population declines of others, and consequent biological diminution of the region can be attributed to many factors. Most prominent are the destruction of natural habitats through dredging, filling, ditching and draining of wetlands; highway and building construction; and pollution of sediments and waters by environmental contaminants such as chlorinated hydrocarbons, heavy metals, oil, pathogens and nutrients associated with various human activities. Other factors include overharvesting of fishery resources, intensive recreational use of shoreline beaches, and expanding populations of certain nuisance and exotic species and their competitive displacement of native species (USFWS, 1991, 1997).

### Restoration Plans

Some examples of restoration plans in the Southern New England/New York Bight subregion are listed below. Additional plans and more detailed information are available through the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

*Comprehensive Conservation and Management Plan for Narragansett Bay*

The CCMP establishes a resource-related objective for each chapter and recommends detailed strategies for resolving a specific aspect of an identified environmental "issue of concern" for Narragansett Bay. The overall issues of concern include: impacts of toxic pollutants, impacts of nutrients and eutrophication, land-based impacts on water and habitat quality, health and abundance of living resources, fisheries management, health risk to consumers of seafood, and environmental impacts on commercial and recreational uses of Narragansett Bay. The plan is divided into three sections: source control and reduction, resource protection and areas of special concern.

*Final Comprehensive Conservation and Management Plan for the NY/NJ Harbor*

The CCMP is a comprehensive plan for the Harbor/Bight watershed. Five primary causes of concern are identified: habitat loss and degradation, toxic contamination, pathogen contamination, floatable debris, and nutrient and organic enrichment. A comprehensive set of commitments and recommendations for each section is provided. A major strength of the CCMP is that it includes many commitments for action from federal, state, interstate and local agencies and also builds on existing base programs of these different agencies.

*Habitat Restoration Plan for the Peconic Estuary*

This plan outlines criteria for selecting habitat restoration priorities and presents several habitats chosen through a nomination process as priorities for restoration. The goals of the plan include: 1) identifying specific habitat restoration projects within the Peconic Estuary and watershed that are ready for immediate funding and 2) identifying natural habitats throughout the region that are most in need of restoration as well as developing criteria for inclusion of projects in a prioritized restoration list.

*Hudson River Estuary Management Action Plan*

This action plan addresses key issues and actions that have been identified through consideration of the Hudson River Estuary Management Plan, public comment at hearings and meetings and the Final Generic Environmental Impact Statement. These issues include managing aquatic resources; preserving upland habitat; open space and scenery; enhancing recreation, interpretation and tourism; revitalizing the river-based economy through environmental protection; and promoting stewardship through partnerships. The plan aims to meet ecological needs of the estuary while serving the many user groups that place demands on it. Identifying, responding to and addressing the needs of the estuary's many diverse user groups is key to implementing a management program that addresses the pressing issues in the estuary and evaluates those needs and programs over time.

*Hudson River National Estuarine Research Reserve*

The Hudson River National Estuarine Research Reserve was established in New York in 1982 and currently encompasses 4,838 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1993. Important habitats at the four reserve components that may be useful for investigation and as reference sites include mixed forests, tidal freshwater wetlands, tidal flats and marshes, and subtidal meadows. Restoration priorities include completing a restoration plan for the Hudson River estuary and a functional assessment model for tidal wetlands. Current restoration projects are freshwater tidal marsh restoration, eagle winter roost creation, nutrient load reduction and Phragmites control. The reserve also serves as a reference site for local researchers and restoration practitioners.

*Jacques Cousteau National Estuarine Research Reserve*

The Jacques Cousteau National Estuarine Research Reserve at Mullica River and Great Bay was established in New Jersey in 1998 and currently encompasses 114,665 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1998. Important habitats that may be useful for investigation and as reference sites include lowland forests, salt marshes, and barrier islands and dunes. The reserve serves as a reference site for the restoration of former salt hay production areas and salt marsh restoration projects.

*Long Island Sound Study Comprehensive Conservation and Management Plan*

This plan characterizes the priority problems affecting Long Island Sound and identifies specific commitments and recommendations for actions to improve water quality, protect habitat and living resources, educate and involve the public, improve the long-term understanding of how to manage the sound, monitor progress and redirect management efforts.

*Management Plan for the Narragansett National Estuarine Research Reserve*

The Narragansett National Estuarine Research Reserve was established in Rhode Island in 1980 and currently encompasses 4,369 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1999. Important habitats that may be useful for investigation and as reference sites include upland fields and forests, freshwater wetlands and ponds, tidal flats, salt marshes and eelgrass. Restoration priorities include restoring flow to a salt marsh bisected by a road and restoring eelgrass . Current restoration projects include salt marsh and eelgrass restoration, prescribed burning, and meadow restoration by altering mowing practices.

*Narragansett Bay Critical Habitat Restoration Plan*

This plan identifies critical habitat status and restoration goals and outlines strategies for achieving those goals. The goals outlined in the plan include the restoration of 1,000 acres of eelgrass and 5,000 acres of salt marsh and the reopening of 152 miles of river passage.

*Natural Resource Restoration Plan for Oil and Chemical Releases in the NY/NJ Harbor Estuary*

This document is a regional restoration plan containing recommendations to restore, replace or acquire the equivalent of natural resources injured by the release of petroleum or hazardous substances into the NY/NJ Harbor Estuary. The plan includes a discussion of the major water bodies emptying into the harbor and the major threats to these areas; criteria for choosing restoration projects; and possible options for restoring areas and resources injured by spills or releases.

## Mid-Atlantic Subregion

### Description

The estuaries of the Mid-Atlantic subregion are mostly bar-built and drowned river valley-type estuaries. The Mid-Atlantic subregion is characterized both by intensely developed urban areas like Wilmington, Del., Baltimore, Md., Washington, D.C., and Norfolk, Va., as well as large rural areas where agriculture dominates the landscape. More than 22 million people live in the Mid-Atlantic watershed, yet 30 percent of the estuarine drainage area in the Chesapeake Bay, Delaware Bay and Delaware Inland Bays is agricultural (NOAA, 1990). The Mid-Atlantic has the largest estuarine and total drainage areas in the Northeast Atlantic region (29,500 and 85,5000 square miles respectively), with almost half of all freshwater entering estuaries in the Northeast Atlantic region flowing through its tributaries (NOAA, 1990; USGS, 1998).

In this subregion, the partnerships are often multi-state, because the estuaries (Chesapeake Bay, Delaware Bay) span multiple jurisdictions. For example, the Maryland Department of Natural Resources Bay Grass Restoration Partnership provides a coordinated approach for promoting citizen-based restoration of bay grass. The program provides the resources and direction necessary for productive restoration projects by individuals, watershed associations, private organizations and others. It is a cooperative effort of the Maryland Department of Natural Resources, citizens and researchers to restore bay grass in areas with suitable habitat conditions.

### Habitat Issues

*Status and Trends*

More than 30 percent (37,000 acres) of coastal habitat in Ocean County, N.J., was lost between 1953 and 1973 (Barnegat Bay Estuary Program, www.bbep.org). At least 25 percent of the Delaware Estuary's original wetlands have been lost, and more than 33 percent of tidal wetlands in Delaware Estuary are invaded with *Phragmites* (Delaware Estuary Program, 1996). More than 25 percent of tidal wetlands in Delaware's Inland Bays were lost between 1938 and 1973 (Delaware Inland Bays Estuary Program, 1995), and more than 2,000 acres of estuarine habitats have been lost in Maryland's coastal bays since the 1930s, mainly from development (Maryland Coastal Bays Program, 1997). The restoration of oyster reefs and shellfish beds is a primary concern in the Mid-Atlantic. Shellfish habitat in Chincoteague Bay has declined from 2,000 acres in the early 1900s to less than 200 acres today (Maryland Coastal Bays Program, 1997). The Chesapeake Bay has lost more than 60 percent of its historical wetlands, and it is estimated that there are more than 2,500 obstructions (e.g., dams, culverts, bridge aprons) to migration of diadromous fish in tributaries to the Chesapeake Bay. The Chesapeake Bay had an estimated 600,000 acres of submerged aquatic vegetation beds at the time of European colonization. In 1997 only 67,000 acres remained (an 88 percent decline) as a result of disease, nutrient enrichment, development and storm disturbance. Populations of the famous Chesapeake Bay oyster have dwindled to two percent of their historical levels because of overharvest and oyster diseases (Chesapeake Bay Program, 1999).

As part of a large-scale mitigation project related to Public Service Electric and Gas Company's Salem Nuclear Power Station, more than 20,500 acres (32-plus square miles) of degraded tidal marshes in the Delaware Estuary are being restored, enhanced or preserved through the Estuary Enhancement Program (PSE&G, 1999*a*). A partnership between Ducks Unlimited and the Chesapeake Bay Foundation has restored more than 3,300 acres of habitat on public and private lands in the Chesapeake Bay watershed (www.cbf.org/about_cbf/rpp/du.htm). The population of Chesapeake Bay striped bass (Morone saxatilis), severely overfished in the late 1970s, has recovered as a result of harvest restrictions and improved habitat conditions (Chesapeake Bay Program, 1999). Through 1998, more than 645 river miles of habitat in tributaries to the Chesapeake Bay were made available to diadromous fish with the removal of obstructions and the installation of fish passage structures (Chesapeake Bay Program, 1999).

*Threats*

The key threats to habitats and species of concern in the Mid-Atlantic subregion, in decreasing order of occurrence in the restoration plans reviewed, are:

- direct habitat alterations due to development, dredging, filling, diking, draining, tidal restriction and alteration, shoreline armoring and hardening, dams, water diversions and low flow, mosquito ditching, and fishing gear;
- pathogens such as *E. coli*, *Pfiesteria,* oyster disease (Dermo, MSX), red/brown tide, and other viruses, bacteria, algae and protozoans that can contaminate or kill shellfish beds;
- nutrient loading from agricultural runoff, urban and stormwater runoff, sewage and septic runoff;
- toxic contamination by heavy metals, PAHs, PCBs, pesticides and other contaminants;
- nuisance, exotic and invasive species (e.g., *Phragmites,* purple loosestrife, Canada geese);
- oil and chemical spills; and
- natural disturbance (e.g., storms, subsidence, rising sea level, predation, grazing).

## Restoration Plans

Some examples of restoration plans in the Mid-Atlantic subregion are listed below. Additional plans and more detailed information are available through the National Strategy Restoration Plan Database (http://restoration.nos.noaa.gov).

*Barnegat Bay Comprehensive Conservation and Management Plan*

This CCMP is a comprehensive environmental management plan for the Barnegat Bay watershed that identifies priority environmental problems and issues of concern. These include stormwater and nonpoint source pollution, nutrient loading, pathogens, water supply, habitat loss and alteration, human activities and competing uses, and fisheries decline. Four action plans and management strategies are put forth to address these problems. Also included in the CCMP are a public participation and education plan, a monitoring program plan, and a section that addresses data management.

*Chesapeake Bay National Estuarine Research Reserve (Maryland)*

The Chesapeake Bay National Estuarine Research Reserve was established in 1985 and currently encompasses 4,820 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1990. Important habitats at the three reserve components that may be useful for investigation and as reference sites include freshwater and flooded hardwood marshes, brackish marshes, and riverine wetlands. Restoration priorities include submerged aquatic vegetation (SAV) at Otter Point Creek and Jug Bay and restoration of wild rice at Jug Bay. Current restoration projects include SAV monitoring and plantings at Otter Point Creek and Jug Bay and the protection of existing wild rice beds and re-establishment of wild rice in previously existing beds at Jug Bay.

*Chesapeake Bay National Estuarine Research Reserve (Virginia)*

The Chesapeake Bay National Estuarine Research Reserve was established in 1991 and currently encompasses 4,435 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1991. Important habitats at the four reserve components that may be useful for investigation and as reference sites include upland and forested wetlands; tidal freshwater, brackish, and salt marshes; intertidal sand and mudflats; and extensive submerged aquatic vegetation beds. Current restoration projects include riparian revegetation and development of stream drainages.

*Delaware Estuary Comprehensive Conservation and Management Plan*

This plan establishes a guide for action to achieve its stated goals for the Delaware Estuary Watershed. Several actions were proposed as habitat enhancement opportunities such as restoring and enhancing poorly functioning tidal wetland impoundments (restoration of 10,000 acres of tidal wetland impoundments within 10 years) and restoring fish passages.

*Delaware Inland Bays Comprehensive Conservation and Management Plan*

In 1988 the Inland Bays Estuary Program convened a management conference to decide what actions to take to protect and restore the estuary. The management conference agreed on goals and objectives for the program which, along with the findings of the report The Characterization of the Inland Bays and other studies, formed the basis for the CCMP. Five action plans are outlined in the plan including an education and outreach plan, an agricultural source action plan, an industrial, municipal and septic system action plan, a land-use action plan, and a habitat protection action plan.

*Delaware National Estuarine Research Reserve*

The Delaware National Estuarine Research Reserve was established in 1993 and currently encompasses 8,600 acres of protected estuarine lands and waters. The reserve management plan was approved by NOAA in 1993 and is currently being revised. Important habitats that may be useful for investigation and as reference sites include forests, freshwater marshes and ponds, salt marshes and mud flats. Restoration priorities include tidal wetlands, Phragmites control, shoreline restoration, reforestation of disturbed uplands and purple loosestrife control. Current restoration projects include shellfish habitat restoration and prescribed burning of Phragmites.

*Maryland Coastal Bays Watershed Conservation and Management Plan*

This plan pinpoints conservation goals for the 177 square miles of the Coastal Bays area and strategies needed to accomplish those stated goals. The plan is divided into four sections: Water Quality, Fish and Wildlife, Recreation and Navigation, and Community and Economic Development. Each section provides information on priority issues, such as bay grasses and fish and shellfish populations, and solutions and actions to address those issues.

*Phragmites-Dominated Wetland Restoration Management Plans*

Three plans have been developed: the Alloway Creek Watershed, the Cohansey River Watershed, and the Delaware *Phragmites*-dominated Wetland Restoration Management Plans. All three plans provide a description of the pre-restoration natural and cultural resources of the various *Phragmites* sites and the restoration design and management provisions for each site.

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